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6 STUDY OF GEOMAGNETIC STORMS,
SOLAR FLARES, AND CENTERS OF ACTIVITY IN 1977,
THE YEAR OF ONSET OF SOLAR CYCLE 21.

10 E. Ruth/Hedeman
Helen Dodson/Prince

The Johns Hopkins University
Applied Physics Laboratory
Laurel, Maryland 20810

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Detailed comparison is made between various types of geomagnetic storms, solar flare activity and coronal holes for the year 1977. The Comprehensive Flare Index (CFI), which quantifies x-ray, optical and radio emission, again proves to be an increasing reliable predictor (statistically) of flare-associated geomagnetic storms as the value of the CFI increases. Two sequences of recurrent geomagnetic storms could be associated with coronal holes extending below 30° heliographic latitude. The two most active regions of the year resulted in

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"flare-sequential" storms in which a coronal hole (and related sequential storms) developed subsequent to the decay of flare production in an adjacent active region.

STUDY OF GEOMAGNETIC STORMS, SOLAR FLARES AND CENTERS
OF ACTIVITY IN 1977, THE YEAR OF THE ONSET OF SOLAR CYCLE 21

TABLE OF CONTENTS

I. INTRODUCTION AND PROCEDURES

Comparisons between observed solar phenomena and certain geophysical effects for (a) years of increasing and maximum solar activity and (b) the year of sunspot minimum have been presented in earlier studies for the Applied Physics Laboratory of the Johns Hopkins University and for the Air Force Geophysics Laboratory. Summaries of the relationships between flares and geomagnetic storms in the seven years of increasing activity in solar cycles 19 and 20 (1955-1957, 1965-1968) have been published by *Dodson-Prince, et al., (1978)*, and the Solar and Geomagnetic comparisons for 1976, the year of minimum are published by *Hedeman and Dodson-Prince (1980)*. The present study attempts to organize the solar and geophysical relationships for 1977, the first year of increasing activity in Solar Cycle 21, and to see how well or poorly they conform to the generalizations developed in the former analysis for years of increasing solar activity in prior cycles and years.

For this study, all geomagnetic storms reported in 1977 by the worldwide network of geomagnetic stations have been evaluated on the basis of the severity and duration of the geomagnetic disturbance. As in our earlier studies, storms with maximum values of 3-hourly $Kp \geq 8$ have been considered as "severe". Storms with maximum values $5 < Kp < 8$ usually have been classified as "moderately severe", and with maximum values $4 < Kp \leq 5$ as "moderate". Weaker disturbances with maximum $Kp \leq 4$ have been omitted from the survey. Solar records and reports have been studied in efforts to recognize the solar phenomena apparently responsible for each geomagnetic disturbance in 1977 for which the 3-hourly $Kp \geq 5$.

In this report, as well as in the earlier studies, the usual flare importance estimates have been supplemented by values of the Comprehensive Flare Index (CFI). The latter is the sum of five quantities that refer to the electromagnetic radiation of the flare and include (1) the magnitude of the ionizing or x-radiation as indicated by the SID, (2) the H_α "importance" of the flare, (3) the magnitude of the ~ 10 cm radio emission (4) the dynamic radio spectrum, and (5) the magnitude of the meter wavelength radio emission. Detailed description of the Comprehensive Flare Index and values of the CFI for all "major" flares 1955-1974 have been published by *Dodson and Hedeman (1971, 1975)*. According to the conventions that we have used, the CFI values for flares range from 0 for subflares without significant ionizing or radio frequency emission to 17 or 18 for the greatest flare-events observed in the

last two decades. We have considered a flare as "major" if it satisfied any one of the following criteria:

Short wave fade or SID, importance ≥ 3

$H\alpha$ flare, importance ≥ 3

10 cm flux ≥ 500 x 10^{-22} ωm^{-2} Hz^{-1}

Type II burst

Type IV radio emission, duration > 10 minutes

Table 1 provides data relating to all "major" flares in 1977 for which the CFI was ≥ 4.

II. SURVEY OF THE 37 PRINCIPAL GEOMAGNETIC STORMS IN 1977

A. Classification and Severity

In 1977 there were 37 geomagnetic storms reported for which the 3-hourly Kp became as great as 5. Data relating to each of these storms and the associated solar circumstances are tabulated in Tables 2A and 2B of this report. Degree of severity of the storms are indicated by "s" for "severe", "ms" for "moderately severe" and "m" for moderate, following the definitions of these terms in Section I. Storms were classified into two types: those with well-defined sudden commencements (SC), and those whose development was gradual (g). There were no geomagnetic storms in 1977 with 3-hourly Kp as high as 8 or 9; in 1976 there had been 3 storms with Kp of 8. For six storms in 1977, Kp was 7. Of the 31 remaining storms in 1977, 11 had Kp's as large as 6, and for 20 storms, maximum Kp was only 5. Geomagnetic disturbance in 1977 was not at especially high levels.

In this survey, we have recognized three principal categories of storms, viz. flare-associated, sequential, and "problem". For ambiguous situations, we have used the expressions "flare-sequential" or "sequential-flare" to indicate the uncertainty. The first member of the double term represents our best judgement in each case. We have considered as flare-associated, those storms that were preceded within the prior 16-84 hours by flares that were above average in either H_α, ionizing, or radio frequency emission. Storms without apparently suitable prior flares but which are in approximately 27 day recurrence patterns have been classified as sequential. Non-sequential, sporadic storms without suitable prior flares are designated as "problem" cases. See Tables 2A and 2B.

TABLE 1

"MAJOR" FLARES IN 1977 WITH COMPREHENSIVE FLARE INDICES ≥ 4

Date	Start of Flare Observation or Event	Position	H α Imp	McMath Plage Number	Event Profile	CFI	Remarks (a)
1977							
Apr. 12	0932	S21 E82	1b	14726	31201	7	III g
Apr. 16	2307	S21 E18	1b	14726	11120	5	† II
June 23	2111	S24 E26	Sn	14815	00013	4	III G, V, U
July 19	(2307)	No flare reported		-	00130	4	--
Aug. 26	0542	S25 E06	Sn	14915	10112	5	III G, V, U
Sept 7	2255	N07 E90	1n	14943	21333	12	GB(10cm); II, III G, V
Sept 9	1630	N08 E84	1n	14943	21332	11	† GB; II, IIIG, V
Sept 16	2123	N07 W20	2n	14943	22333	13	† GB; II, IIIg
Sept 19	0955	N08 W57	3b	14943	33232	13	† II, IIIg; GLE
Sept 20	0251	N09 W59	2n	14943	22232	11	† II, IIIg
Sept 24	(0552)	No flare reported		-	00133	7	† II, IIIG, V; GLE
Oct. 4	(2325)	No flare reported		-	00031	4	II, IIIg, V
Oct. 6	0425	N31 W59	1n	14967	21233	11	II, IIIg, V
Oct. 12	0150	N06 W02	1b	14979	21233	11	† II, IIIG, V
Oct. 31	0411	N20 E70	Sn	15017	10112	5	IIIG
Nov. 7	0531	S23 W45	1n	15016	01131	6	II
Nov. 22	0945	N24 W40	2b	15031	22332	12	† GB; IIIg; GLE
Dec. 6	(1555)	No flare patrol		-	0-133	≥7	IIIg, V
Dec. 6	1935	S18 W18	Sb	15049	10214	8	IIIg, V, U 200 MHZ Flux = 15,000
Dec. 10	0301	S27 E16	1b	15056	21232	10	† II, IIIg, V
Dec. 24	(1307)	No flare reported		-	10112	5	IIIG, V
Dec. 26	0150	S26 W57	Sf	15074	20112	6	--
Dec. 27	1045 1055	S25 W79 S27 W13	1n Sf	15074 15077	11232	9	II, IIIg
Dec. 30	0406	S16 E38	1n	15081	21211	7	IIIG, U

(a) A † in this column indicates that the flare is associated with a subsequent geomagnetic storm. The other entries primarily provide details of the radio frequency emission. II indicates a Type II burst in addition to the reported Type IV or continuum emission. Nomenclature follows SGD (see Descriptive Text). GLE indicates ground level cosmic ray event.

TABLE 2A

PRINCIPAL GEOMAGNETIC STORMS IN 1977

Storm Rank	Class of Storm	Time of Start (U.T.)	C Duration	Characteristics Type	Deg.	Max. Daily Values K_p	A_p	Max. 3-Hr. K_p
1	Problem	Dec. 1^d 20-	1.5d	g	ms	44	69	7
2	Flare- sequential	Sept. 21^d 2044 This storm immediately follows storm number 3. It also is in a sequential storm pattern.	2.4d	SC	ms	42	63	7
3	Flare	Sept. 19^d 1143	2.2d	SC	ms	41	64	7
4	Problem*	Oct. 26^d 2330	2.7d	SC	ms	41	62	7
5	Sequential*	July 29^d 0027 Second member of good sequence.	1.5d	SC	ms	40	61	7
6	Sequential	April 6^d 12-	3.8d	g	ms	37	49	7
7	Sequential	May 1^d 18-	1.8d	g	ms	44	66	6
8	Sequential- flare	April 19^d 0106	2.3d	SC	ms	39	48	6
9	Sequential(?)	Nov. 12^d 02-	3.7d	g	ms	38	42	6
10	Problem	Aug. 5^d 00-	2.0d	g	ms	36	40	6
11	Sequential- flare	Dec. 10^d 20-	3.0d	g	ms	36	38	6
12	Sequential	Aug. 17^d 04-	3.0d	g	ms	30	29	6
13	Sequential	Oct. 18^d 02-	1.8d	g	m	28	28	6
14	Problem*	July 6^d 1038	1.2d	SC	m	27	28	6
15	Sequential(?)*	May 11^d 06-	1.4d	g	m	27	24	6
16	(Solar event)* (See Table 2B)	Sept. 26^d 07-	1.3d	g	m	24	24	6
17	Sequential*	Apr. 24^d 10-	1.0d	g	m	23	22	6
18	Sequential	Mar 8^d 18-	5.8d	g	m	36	38	5
19	Sequential	Jan. 28^d 1840	3.0d	SC	m	33	30	5

TABLE 2A (Cont'd)

Storm Rank	Class of Storm	Time of Start (U.T.)	C Duration	Characteristics Type	Deg.	Max. Daily Values K_p	A_p	Max. 3-Hr. K_p
20	Sequential*	July 19^d 02-	2.4d	g	m	32	29	5
21	Sequential*	Aug. 11^d 01-	1.0d	g	m	32	28	5
22	Flare-sequential*	Sept. 12^d 2113	1.4d	SC	m	31	28	5
23	Sequential*	July 14^d 02-	3.5d	g	m	31	27	5
24	Sequential-flare*	Oct. 11^d 13-	2.1d	g	m	30	28	5
25	Sequential*	Apr. 2^d 2157	2.2d	SC	m	29	24	5
26	Sequential	May 14^d 21-	3.0d	g	m	29	22	5
27	Sequential*	Aug. 25^d 07-	3.0d	g	m	28	27	5
28	Sequential(?)	Oct. 21^d 23-	1.4d	g	m	28	22	5
29	Sequential	Aug. 9^d 14-	0.8d	g	m	27	20	5
30	Sequential	Feb. 22^d 11-	3.6d	g	m	26	18	5
31	Flare	Nov. 25^d 1225	2.1d	SC	m	25	19	5
		Second SC on Nov. 26^d 1704 UT						
32	Flare-sequential	Oct. 14^d 1151	1.6d	SC	m	25	19	5
33	Problem*	Dec. 4^d 14-	1.1d	g	m	24	18	5
34	Sequential*	Feb. 17^d 15-	1.5d	g	m	23	17	5
35	Sequential*	Mar. 27^d 0607	2.0d	SC	m	23	15	5
36	Sequential	May 4^d 0417	2.1d	SC	m	22	19	5
37	Problem*	Jan. 11^d 0912	1.5d	SC	m	22	14	5

*Indicates concomitant sector boundary passage.

TABLE 2B

FLARE AND OTHER SOLAR ASSOCIATIONS WITH GEOMAGNETIC STORMS IN 1977

Associated Flare Data

Storm Rank	Date and Time	Position Lat. CMD	McMath Plage Number	Imp	Profile	CFI	Particle Emission	Δt to Storm
1	No suitable prior flares. Possibly an isolated major storm unless first member of short and weak sequence.						Major proton event of Nov. 22 still in progress.	-
2	Sept. 20^d 0251	N09 W59	14943	2n	22232	11	In progress	1^d 17^h
3	Sept. 16^d 2123	N07 W20	14943	2n	22333	13	Electrons Protons (40-80 MeV)	2^d 14^h
	Sept. 19^d 0955	N08 W57	14943	3b	33232	13	Electrons Protons, GLE (40-80 MeV)	Contributor to second maximum on 21st
4	No suitable prior flares. An isolated major storm not obviously sequential.						-	-
5	No known suitable prior flares. Prior particle event July 26^d 12^h U.T. with no known solar event.						Electrons Protons (40-80 MeV)	(2^d 12^h from particle event)
6	No suitable prior flares.						-	-
7	No suitable prior flares.						-	-
8	Apr. 16^d 2307	S21 E18 This flare is possibly the source of the sudden commencement.	14726	1b	11120	5	Protons (0.9-1.8 MeV)	2^d 02^h
9	No suitable prior flares. Possibly a member of a 28-day sequence.						-	-
10	No suitable prior flares. No well defined sequence.						-	-
11	Dec. 10^d 0301	S27 E16 Also a member of a 27-day recurrence pattern.	15056	1b	21232	10	-	-
12	No suitable prior flares.						-	-
13	No suitable prior flares.						-	-
14	No suitable prior flares. Not sequential.						-	-
15	No suitable prior flares. May be last member of very weak sequence.						-	-
16	No suitable prior flare reported on visible disk. Sept. 24^d 0554 - Types II and IV. Flare-rich Plage 14943 was several days beyond the west limb.				00133	7	PCA, GLE Protons (40-80 MeV)	2^d 01^h
17	No suitable prior flare. Member of very weak sequence which may be continuation of a strong sequence in progress in second half of 1976.						-	-

TABLE 2B (Cont'd)

Storm Rank	Date and Time	Position Lat. CMD	McMath Plage Number	Imp	Profile	CFI	Particle Emission	Δt to Storm
18	No suitable prior flare.						-	-
19	Appears to be a member of a weak sequence.						-	-
20	No suitable prior flares. Probably sequential.						-	-
21	No suitable prior flares.						-	-
22	Sept. 9^d 1630	N08 E84	14943	1n	21332	11	Protons in progress	$3^d\ 05^h$
23	No suitable prior flares.						-	-
24	Oct. 8^d 1230	N06 E44	14979	1n	11121	6	-	$3^d\ 00^h$
25	No suitable prior flares.						-	-
26	No suitable prior flares.						-	-
27	No suitable prior flares.						-	-
28	No suitable prior flares. It may be sequential with storm No. 16.						-	-
29	No suitable prior flares.						-	-
30	No suitable prior flares.						-	-
31	Nov. 22 0945	N24 W40	15031	2b	22332	12	GLE Electrons Protons (40-80 MeV)	$3^d\ 03^h$
32	Oct. 12 0150	N06 W02	14979	1b	21233	11	Electrons Protons (40-80 MeV)	$2^d\ 10^h$
	The storm is also possibly a member of a 28 day sequence. See storms Nos. 9 and 11.							
33	No suitable prior flares. Not sequential. Isolated storm.						-	-
34	No suitable prior flares. First member of a weak sequence which includes storm No. 15.						-	-
35	No suitable prior flares. Member of weak sequence.						-	-
36	No suitable prior flares. May be continuation of sequential storm No. 7.						-	-
37	No suitable prior flare. Storm may be a member of two-rotation sequence.						-	-

Very few of the geomagnetic storms in 1977 were ambiguously associated with prior solar flares. Only 2 of the 37 storms in Table 2 carry this classification. For 6 additional cases, significant prior flares preceded storms in 27 day sequences. For Storm No. 16 (in Table 2) on September 26, it is believed that there was a causitive, prior, flare-like "solar event" on September 24 because of the occurrence of radio frequency bursts of Types II and IV, PCA and the onset of a 40-80 MeV proton enhancement. No suitable associated H_{α} flare was reported as observed on the visible solar disk. Flare-rich plage 14943 was several days beyond the west limb, and the event is attributed to this region. Finally 5 storms remain as "problem" cases (see Table 3). It is interesting to note the great similarity in the frequency and classification of geomagnetic storms in 1976, the year of sunspot minimum, and in 1977, the first year of the new solar cycle. However, as mentioned earlier, the greatest storms of 1976 were more severe (max. 3-hourly Kp = 8) than the greatest storms in 1977 (max. 3-hourly Kp was only 7) (see Table 3).

B. Flare-Associated Storms in 1977

"Major" solar flare activity in 1977 was very limited during the first 7 months of the year. Although there were 24 "major" flare events in 1977 which also had CFI ≥ 4, only 5 of these significant flares took place in the first seven months of 1977. There were no instances of Comprehensive Flare Indices ≥ 11 before September and the coming of flare-rich plage 14943 (CMP September 15) (see Table 1).

Although the number of flares apparently associated with subsequent geomagnetic storms in 1977 was small, they followed reasonably closely the relationships previously reported by *Dodson-Prince et al. (1978)* between storm production and "major" flares with certain values of the Comprehensive Flare Index (CFI) in the four-year interval 1965-1968 (See Table 4 and Figure 1). For the many "major" flares in 1977 with CFI < 4 (a total of 41 cases), no subsequent storms were recorded. As the CFI became larger, the proportion of "major" flares followed by geomagnetic storms increased. About half of the "major" flares with CFI's between 10 and 12 were storm-associated, and for values of CFI ≥ 13 in 1977 the proportion with subsequent storms rose to 100%. Apparently, the data given in Figure 5 of *Dodson-Prince et al. (1978)* and here reproduced as Figure 1 of this report, would have provided useful guidance for the prediction of flare-associated geomagnetic disturbance in 1977. If possible, further tests of the reliability of this survey should be undertaken for later years.

TABLE 3

CLASSIFICATION OF PRINCIPAL GEOMAGNETIC STORMS IN 1976 AND 1977

Classification	Number 1976	Number 1977
Flare	2	2
Flare-Sequential	2	3
Sequential	21	23
Sequential-Flare	3	3
"Solar event" (H_α flare not reported)	-	1
Problem	6	5
Total	34	37

Max. 3-hourly K_p	1976	1977
8	3	-
7	2	6
6	10	11
5	19	20

TABLE 4

NUMBER AND PERCENTAGE OF "MAJOR" FLARES ASSOCIATED WITH ONSET OF GEOMAGNETIC STORMS

	1965-1968†			1966			1977		
	Number		Percent with Storm	Number		Percent with Storm	Number		Percent with Storm
CFI	Total	Storm Associated		Total	Storm Associated		Total	Storm Associated	
1-3	56	0	0%	17	0	0%	41	0	0%
4-6	99	17	17%	18	1	5%	9	1	11%
7-9	75	19	25%	17	3	17%	6	1	17%
10-12	27	11	41%	12	6	50%	7	5	71%
13-17	12	11	92%	5	5	100%	2	2	100%
Total	269	58	22%	69	15	22%	65	9	14%

† Data taken from AFGL-TR-78-0267.

In 1977, there were 2 "major" flares with CFI of 11 and 12 that were not storm associated. The first (CFI of 12) on September 7 was at the east limb (E90°), an unfavorable location for storm production (see Figure 2 which also has been reprinted from *Dodson-Prince, et al., 1978*). The second non-storm-producing flare was on October 6 with CFI of 11, at N31° W59°, and was accompanied by a spray that extended 0.3 of a solar radius beyond the west limb. The high latitude of this flare and its close proximity to the west limb may have made propagation of storm particles to earth difficult. The heliographic longitude of the flare falls in the range where the frequency of storm causation by flares apparently diminishes rapidly (see Figure 2).

Finally, in the comparison of flares and subsequent geomagnetic storms, one is led to ask why the flare on November 22, 1977 at N24 W40, with CFI of 12 and associated with an enhancement of electrons and 40-80 MeV protons as well as a ground level cosmic ray event (one out of only 3 in 1977), was followed by such a relatively weak geomagnetic storm. The maximum three-hourly value of Kp in this storm did not become greater than 5 and the storm is ranked as No. 31 in Table 2A. The state of the interplanetary medium apparently often plays an important role in the propagation of storm-causing particles.

C. Sequential Storms

In 1977 we have classified 29 geomagnetic storms as occurring in approximately 27 day sequential patterns. Two of the sequences are well defined and of relatively long duration. The first of these principal 27-day sequences began in December 1976 and continued through early May 1977. These storms occurred four or five days after the successive central meridian passages of the principal part of a north polar coronal hole with extension below 30° North latitude. The geomagnetic sequence fails in June 1977 when the polar coronal hole is apparently confined to latitudes higher than 30°. Coronal hole information is based on λ 10830 data prepared by the Space Environment Services Center in Boulder, Colorado.

The second well established pattern of recurrent geomagnetic storms in 1977 begins on July 1 and continues apparently until May 1978. In 1977, according to the λ 10830 data, this series of geomagnetic storms was preceded by passage across the solar disk of an *equatorial* coronal hole in Northern latitudes (see Figure 3).

The two principal sequences described above included about half of the apparently sequential storms in 1977. The remaining recurrent storms were more scattered in their patterns and their relationships to coronal holes were not obvious on the basis of material available to us. These less well

defined sequential storms in 1977 included storms that constitute the last members of the best defined sequence of the second half of 1976 (see March 27, 1977, storm No. 35, Table 2A).

D. The "Problem" Storms

According to our survey of the data, there were 6 geomagnetic storms in 1977 which were not in a 27-day recurrence pattern, nor could we find appropriate prior flares for association with the storms. The storm of December 1, apparently the most severe storm of the year, falls in this category. Likewise, the storm of October 26 (No. 7 in rank) was an isolated storm without apparent flare causation. This storm, however, was concomitant with a sector boundary passage at the earth. The same is true for 3 of the remaining 4 "problem" storms in 1977 (i.e., No. 14 on July 16, No. 33 on December 4, and No. 37 on January 11). Thus there were only two storms in 1977 that were not either flare-associated, sequential, or at the time of a sector boundary passage. These two truly "problem" storms in 1977 were the most severe storms of the year on December 1 (previously mentioned) and the storm with maximum Kp of 6 on August 5 (No. 10 in storm rank).

III. LOCATION OF IMPORTANT CENTERS OF ACTIVITY IN 1977

In 1977 there were two centers of activity whose level of activity, as measured by flares, x-ray and radio emission, spot area and complexity, etc., clearly exceeded that of all regions. The first of these important plages, McMath Plage 14822 crossed the central meridian on June 30 in latitude N16°. During its next passage across the solar disk (in July) when its activity had diminished, a low latitude coronal hole developed in the immediately preceding longitudes and the first member of a well established 27-day recurrent storm sequence was observed at earth (see Figure 3). In August the coronal hole and associated geomagnetic storm were again observed. The coronal hole information has been taken from the preliminary synoptic charts of λ 10830 data prepared by the Space Environment Services Center in Boulder, Colorado. In this instance, and as already indicated in the survey of geomagnetic data in 1976, the coronal hole and recurrent storm pattern do not develop until the possibly related particle source (the center of activity) is greatly diminished or had disappeared.

The second great center of activity in 1977, McMath Plage 14943 crossed the Central Meridian on September 15.5 in latitude N08° and was the source of several storm-associated flares. This center of

activity was *closely* followed on the solar disk by the continuing and growing equatorial (i.e., low latitude) coronal hole of July and August mentioned above (see Figure 3). Some of the geomagnetic storms apparently stemming from flares in Plage 14943 occur also in the 27-day recurrent storm pattern associated with this adjacent coronal hole. Such "flare-sequential" storm situations serve to emphasize the complexity of the apparently possible relationships between centers of activity, coronal holes, and solar wind streams. Careful study is needed before confident patterns in such phenomena can be recognized.

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FIGURE CAPTIONS

FIGURE 1 Number and percent of "major" flares with different values of the comprehensive flare index associated with geomagnetic storms with maximum 3-hourly Kp $\geq$ 5 (1965-1968).

FIGURE 2 Central Meridian distance and importance of flares associated with geomagnetic storms of different severities, 1955-57 and 1965-68.

FIGURE 3 Composite plot of Carrington Longitudes of Central Meridian passage of the two "great" centers of activity in 1977, coronal holes, and the times of occurrence of geomagnetic storms as indicated by the L_o (heliographic longitude) of solar central meridian on dates of storm occurrence.

Portions of Carrington Rotations are shown from May 1977 through January 1978. Time increases from left to right. Heliographic longitudes in degrees are indicated across the top of the diagram. Corresponding Carrington rotation days are indicated across the bottom.

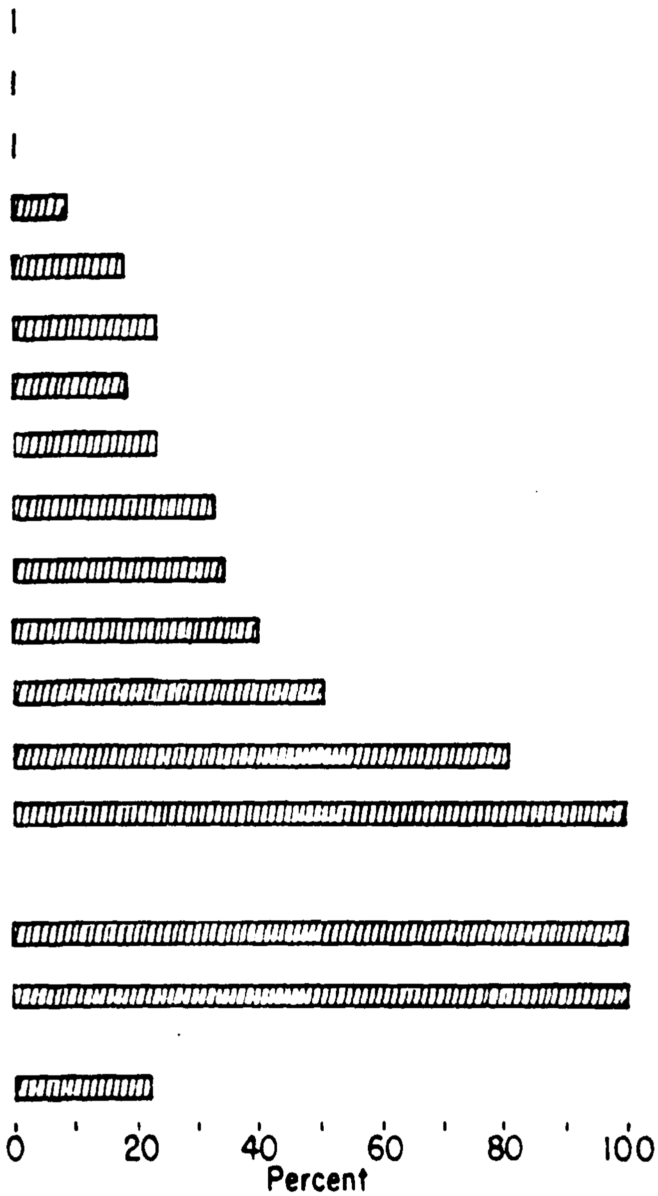
Plages are shown by circles whose sizes reflect the areas and intensities of the regions. Successive returns in subsequent rotations are indicated by connecting lines. Numbers within parentheses give the Active Region Indices for "major" regions for the time interval covered by the diagram.

Intervals of geomagnetic disturbance are represented by solid horizontal bars plotted at the Carrington longitudes corresponding to the values (L_o) for the solar central meridian on the days of storm occurrence. Dashed lines show the extent in Carrington longitude of a low latitude sequential coronal hole as shown in preliminary λ 10,830 data prepared at the Space Environment Services Center, Boulder, Colorado.

Number and Percent of "Major" Flares
with Different Values of the Comprehensive Flare Index (CFI),
Associated with Geomagnetic Storms with Maximum 3-Hourly Kp ≥ 5, 1965-1968.

Number of "Major" Flares (1965-1968)

C F I	Total	Without Storm	Storm Associated	Percent with Storm
1	13	13	0	0
2	16	16	0	0
3	27	27	0	0
4	33	30	3	9
5	31	25	6	18
6	35	27	8	23
7	21	17	4	19
8	26	20	6	23
9	28	19	9	32
10	12	8	4	33
11	5	3	2	40
12	10	5	5	50
13	5	1	4	80
14	4	0	4	100
15	–	–	–	–
16	2	0	2	100
17	1	0	1	100
Total	269	211	†58	22



† Includes the "ambiguous" as well as the uniquely storm-associated flares.

Fig. 1

Central Meridian Distance and Importance of Flares Associated with Geomagnetic Storms of Different Severities; 1955-57 and 1965-68.

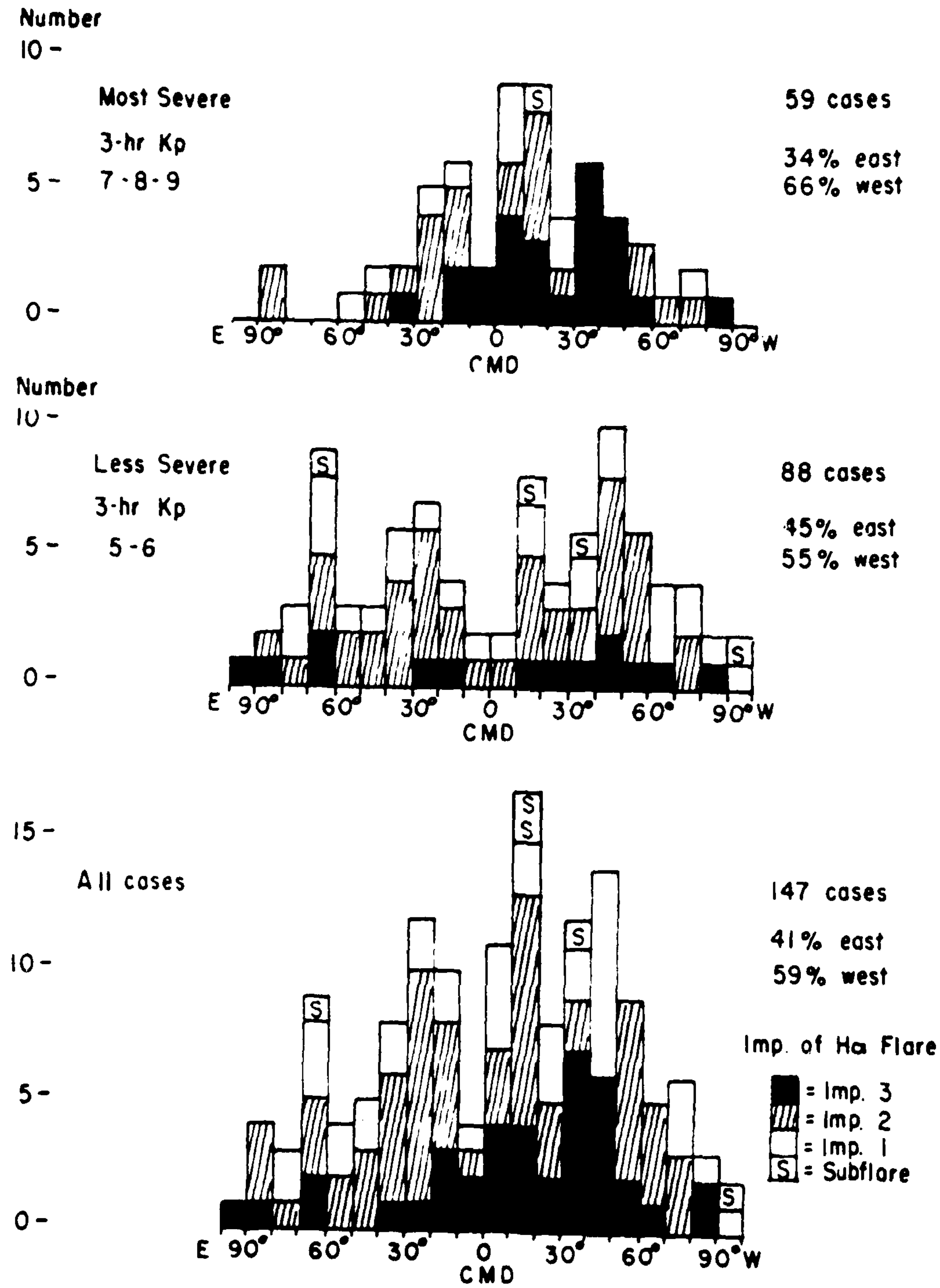


Fig. 2

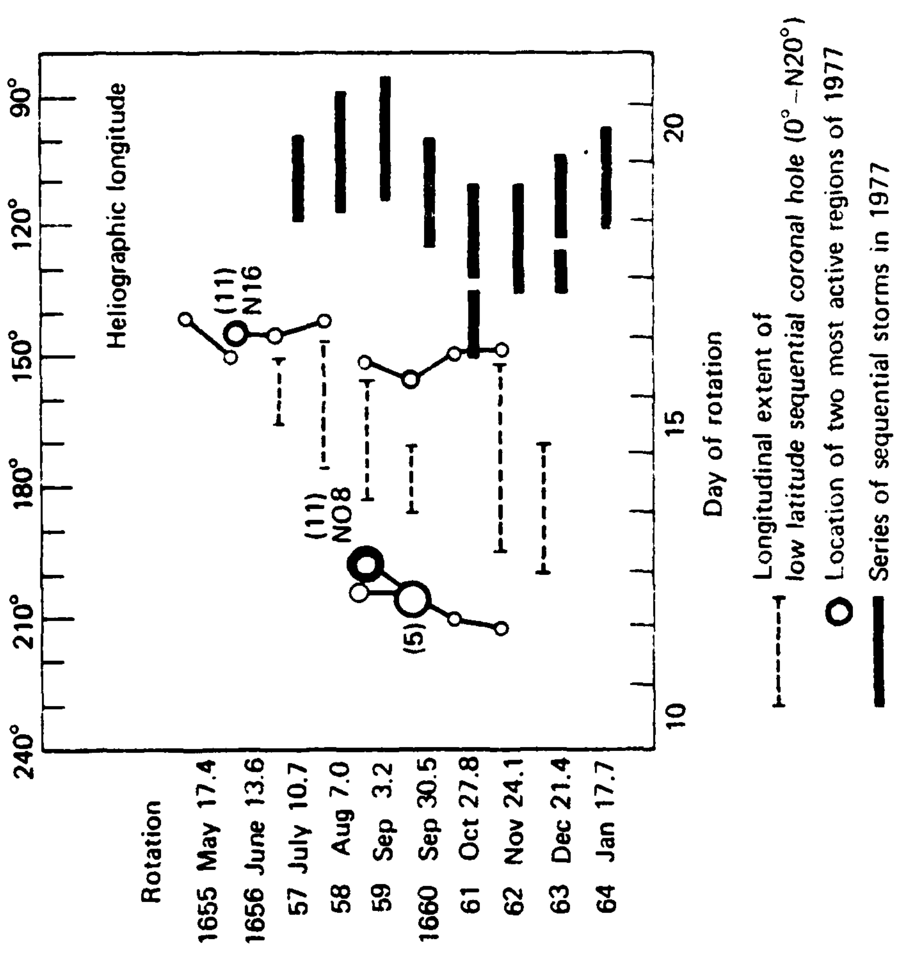

Heliographic longitude
90°
120°
150°
180°
210°
240°
Rotation
1655 May 17.4
1656 June 13.6
57 July 10.7
58 Aug 7.0
59 Sep 3.2
1660 Sep 30.5
61 Oct 27.8
62 Nov 24.1
63 Dec 21.4
64 Jan 17.7
(11) N16
(11) NO8
(5)
10
15
20
Day of rotation
Longitudinal extent of low latitude sequential coronal hole (0° – N20°)
Location of two most active regions of 1977
Series of sequential storms in 1977

Fig. 3

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